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THE DOUBLE CREST OF SECOND WATCHUNG MOUNTAIN.[1]

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Twenty miles west of the Palisades of the Hudson River rise the prominent ridges of the Watchung Mountains, which extend southwestward from a point ten miles north of Paterson, N. J., almost to Somerville, a distance of forty miles. The parallel ridges of these mountains are the outcropping edges of extrusive trap sheets imbedded in a series of red shales and sandstones which constitute the upper (Brunswick) member of the Newark system in New Jersey. In general these strata have an average northwesterly dip of 12 to 15 degrees. It has long been known, however, that the recurved ends of the Watchung Mountains swing around the extremities of the boat shaped Passaic Basin syncline, which has been cut off on the northwest by a fault along the border of the crystalline rocks of the Highlands.

The hook-shaped southwestern portion of Second Mountain (see maps, Figs. 1 and 2) is much broader than elsewhere and for a distance of seventeen miles the crest is distinctly double. This condition has been explained[2] as the result of a curved longitudinal fault parallel to the present outcrop of the trap sheet. While entirely consistent with the facts, so far as at present known, the probability of such a coincidence is so extremely small that, in the absence of positive proof of faulting, this hypothesis must be regarded as exceedingly doubtful.

It is the object of the present paper to explain the observed conditions upon an altogether different basis, and in a manner requiring no assumptions that are in any way improbable in the light of our present understanding of the geologic history of the region. For this purpose brief discussions are here given of (1) the facts requiring explanation, (2) the interbedded shale hypothesis, (3) the curved longitudinal fault hypothesis, (4) the hypothesis of double flow with

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[2] Darton, *Bull. U. S. Geological Survey No.* 67, p. 22; Kümmel, *Ann. Report Geol. Survey of N. J.*, 1897, p. 125.

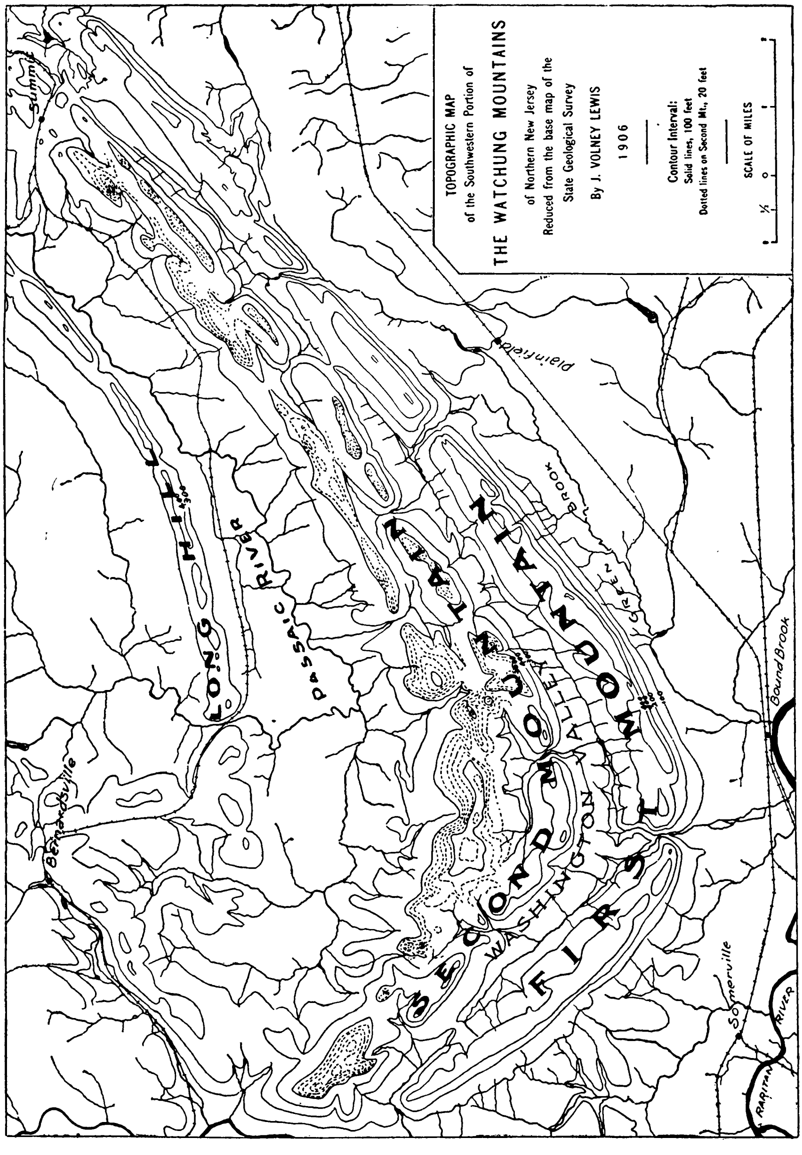
TOPOGRAPHIC MAP
of the Southwestern Portion of
THE WATCHUNG MOUNTAINS
of Northern New Jersey
Reduced from the base map of the
State Geological Survey
By J. VOLNEY LEWIS
1906
Contour Interval:
Solid lines, 100 feet
Dotted lines on Second Mt., 20 feet
SCALE OF MILES
½
0
1
2
Summit
Plainfield
Bound Brook
Somerville
RARITAN RIVER
Bernardsville
LONG HILL
PASSAIC RIVER
SECOND MOUNTAIN
FIRST MOUNTAIN
GREEN BROOK
WASHINGTON VALLEY

FIG. 1

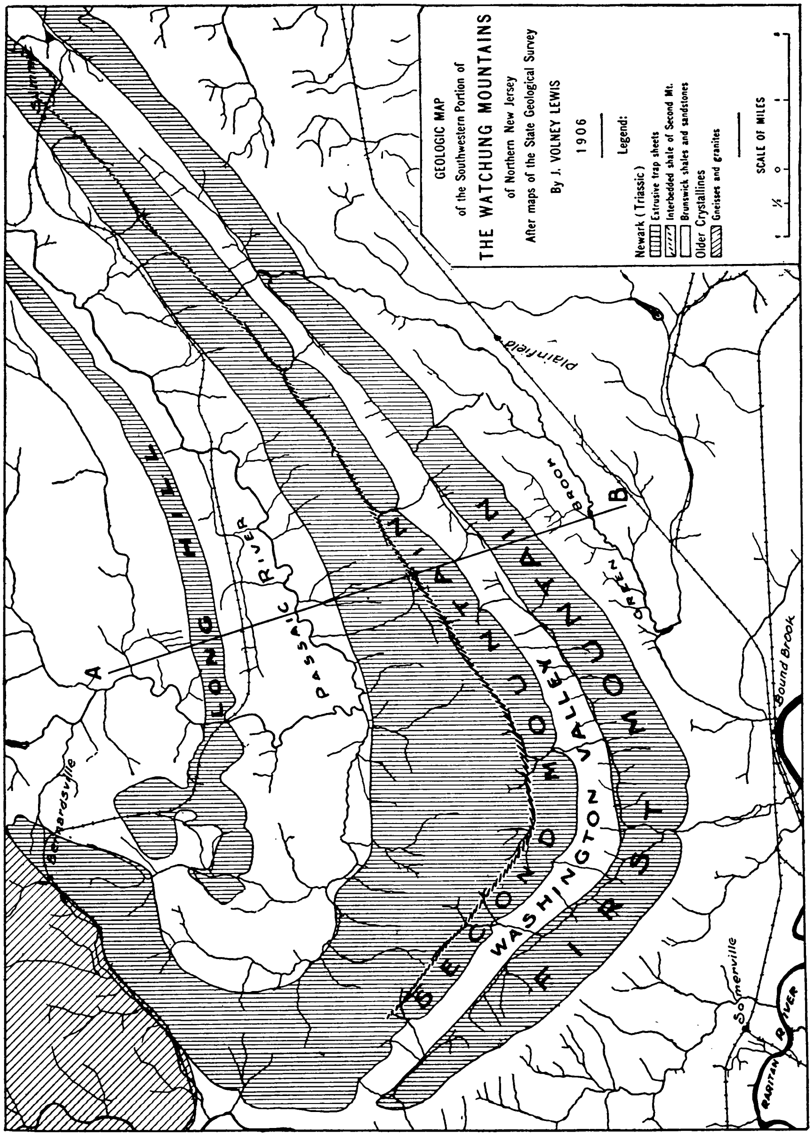
GEOLOGIC MAP
of the Southwestern Portion of
THE WATCHUNG MOUNTAINS
of Northern New Jersey
After maps of the State Geological Survey
By J. VOLNEY LEWIS
1906
Legend:
Newark (Triassic)
Extrusive trap sheets
Interbedded shale of Second Mt.
Brunswick shales and sandstones
Older Crystallines
Gneisses and granites
SCALE OF MILES
1 ½ 0 1 2
Summit
Plainfield
Bernardsville
Somerville
Bound Brook
RARITAN RIVER
PASSAIC RIVER
LONG HILL
SECOND MOUNTAIN
FIRST MOUNTAIN
WASHINGTON VALLEY
GREEN BROOK
A
B

FIG. 2

intercurrent warping here advocated. The last is somewhat more fully presented and its bearings upon subsequent geologic history discussed. The others are summarized from Kümmel's report.[1]

1. *Conditions requiring explanation.*—The width of outcrop of trap along Second Mountain varies greatly. Along much of its course the crest is double, as pointed out above, and in the intervening valley shale has been found at a number of places either in wells or at the surface. At both ends of the ridge, however, the crest is single, and no shales appear within the trap area in the gorge of the Passaic River at Little Falls. In a well at Mount St. Dominic Academy, Caldwell, the following section was found: Glacial drift, 100 feet; trap rock, 775 feet; total 875 feet; shale at the bottom. A well bored for Mr. Keane on the inner crest of Second Mountain, near East Livingston, and but three miles from the well at Caldwell, furnished the following section: soil, 5 feet; trap rock, 90 feet; brown sandstone, 51 feet; trap rock, 381 feet; total, 527 feet. Both wells are in such location as to pass through an interbedded layer of sediments, if such existed. Over the country between the two crests Darton found red shale fragments which he regarded as portions of underlying sediments.

2. *The interbedded shale hypothesis.*—Kümmel considered the hypothesis that Second Mountain consists of two successive flows of lava separated by a stratum of sediments, but rejected it for the following reasons: (1) the crest is single at both ends of the ridge; (2) no trace of shale is found at either locality; (3) the gorge at Little Falls and the deep well at Caldwell show no shale. The "brown sandstone" reported from Mr. Keane's well he regarded as probably a red-brown variety of trap.

3. *The hypothesis of a "curved longitudinal fault."*—Under the seeming necessity of choosing between the interbedded shale hypothesis above referred to and that of a fault which possesses the remarkable property of conforming exactly with the present outcrop around the sharply recurved southwestern extremity of Second Mountain, both Darton and Kümmel accepted the latter, in spite of the fact that "no direct evidence of faulting beyond that furnished by the topography—the repetition of the beds—was found. . . . . Indirect

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[1] *Loc. cit.*, pp. 125 ff.

evidence derived from a study of the width of the outcrop of the trap and the apparent thickness along different section lines" may be summarized as follows: On the assumption (1) that there was no deformation in the intervals between the various lava flows of the Watchung ridges (nor accompanying the flows); (2) that sedimentation was uniform throughout the area; (3) that the lava sheets are approximately of uniform thickness, their bases must have been originally parallel. Allowing for known faults this is still true of First and Second mountains; but from the base of the Second Mountain sheet to that of the third (Long Hill) is a distance that varies greatly in different sections, and the apparent differences are greater where the double crests of Second Mountain are most marked. This variation is ascribed to faulting which Darton assumed further to be confined to the areas of the present trap outcrop.

Kümmel points out several very obvious defects in the above reasoning: (1) that any or all of these various assumptions may be incorrect; (2) that there is no conclusive reason for supposing that faulting is restricted to the trap areas of the present surface; (3) that variations in thickness of either the trap of Second Mountain or of the overlying shales would vitiate the conclusions. Notwithstanding these elements of uncertainty and improbability, however, the estimates based on the above assumptions are regarded as "indicating quite clearly that some faulting has occurred," and as "strengthening the argument derived from the double crest." Hence the conclusion that "it is safe to assume that Second Mountain is traversed for much of its extent by a curved longitudinal fault."

4. *The hypothesis of double flow with intercurrent warping.*—The explanation here advanced is believed to be entirely consistent with all ascertainable facts and to be free from improbable assumptions. It is practically the interbedded shale hypothesis described above, freed from the restrictions of stability and uniform sedimentation in the intervals between the lava flows.

The present condition of the Newark rocks throughout eastern North America shows that they have been subjected to universal deformation, and as yet there has been discovered no means of defining the exact stage in their history at which the disturbing movements began. The slightest warping of the surface at any stage of the sedimentation would have its inevitable effect upon the thickness and distribution of the subsequent deposits. This is particularly true of shallow water and continental formations, in one or both of which categories the Newark beds must be placed.

The proposed hypothesis to account for the conditions above enumerated in Second Mountain may be stated as follows: After the eruption of the trap sheet of First Mountain and the deposition of some 600 feet of overlying sandstones and shales, a second eruption occurred, forming a lava flow averaging probably 500 feet thick over the same region. This is the trap of the outer crest of Second Mountain. With this outflow began a gradual depression of the southern axial region of the great Passaic Basin syncline, the region northeastward from Somerville. In consequence of this warping, subsequent deposits were concentrated in this region, tending to build it up to the level of the adjoining area, but before this condition was finally attained deposition was again interrupted by eruption. Another lava sheet of about 500 feet average thickness was spread over the region, but not uniformly nor even approximately so, as the preceding flow had been. Over the shales in the area of subsidence the maximum thickness was at least 800 feet, while in the adjoining regions where it rested on the unburied flanks of the preceding flow it probably did not exceed 200 feet in thickness. Thus the two flows, separated by a brief interval of deposition, merged into one on the sides of the incipient syncline, but were elsewhere separated by a thin stratum of shale. (See section Fig. 3.) This refers, of course, to the portions of these sheets still preserved to us, all of which are involved in the Passaic Basin syncline.

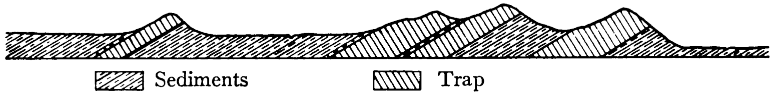

FIG. 3

When by later movements their upturned edges were exposed to the forces of weathering and erosion, the soft interbedded shales quickly wore away to a lower level, thus forming the continuous valley curving conformably with the outcropping edges of the adjacent trap sheets above and below. The valley between the crests of Second Mountain is therefore considered to be exactly comparable to Washington Valley, between First and Second mountains. It is shallower and the escarpment of the overlying trap outcrop is less pronounced because of the limited thickness of the interbedded shales.

Evidence of continued depression in the same synclinal region is found in the sediments between Second Mountain and the overlying trap sheet of Long Hill. There is a decrease of one-fourth in the thickness of the intervening shales at Madison, as compared with those at Millington, and a much more rapid thinning out toward the west. The trap sheet of Long Hill is also thicker about Millington, but this may be due in part only to the original inequality of the surface upon which it was laid.